This listing of claims will replace all prior versions, and listings, of claims in the application:

Listing of Claims:

1. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

2. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

said noise spatial eigenmatrix calculation unit applies the eigenvalue factorization to the unitary-transformed correlation matrix.

3. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to product U^HU of upper triangular matrix U by cholesky factorization.

4. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

5. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product U^HDU of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

6. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

7. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

8. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

9. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

10. (Original) A radio-wave arrival-direction estimating apparatus according to claim 1, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

11. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a noise spatial eigenmatrix calculation unit for calculating a noise spatial eigenmatrix by eigenvalue factorization of the correlation matrix, one of a row and a column of the noise spatial eigenmatrix being an eigenvector belonging to a noise eigen-space;

a triangular matrix calculation unit for factorizing a matrix including a product of the noise spatial eigenmatrix and a conjugated and transposed matrix of the noise spatial eigenmatrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

12. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value from said arrival-angle evaluation unit.

13. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

said inverse matrix calculation unit calculates an inverse matrix of the unitary-transformed correlation matrix.

14. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product $U^{H}U$ of upper triangular matrix U by cholesky factorization.

15. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

16 (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product U^HDU of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

17. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

18. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

19. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

20. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

21. (Original) A radio-wave arrival-direction estimating apparatus according to claim 12, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

22. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

an inverse matrix calculation unit for calculating an inverse matrix of the correlation matrix;

a triangular matrix calculation unit for factorizing the inverse matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

23. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of the upper triangular matrix and the lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

24. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

25. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein said triangular matrix calculation unit factorizes input matrix R to product U^HU of upper triangular matrix U by cholesky factorization.

26. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

27. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein said triangular matrix calculation unit factorizes an input matrix to product U^HDU of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

28. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

29. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

30. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

31. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

32. (Original) A radio-wave arrival-direction estimating apparatus according to claim 23, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined

angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

33. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an inverse matrix calculation unit for calculating an inverse matrix of the one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the inverse matrix of the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

34. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

35. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34 further comprising a unitary transforming unit for unitary-transforming the correlation matrix, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

said triangular matrix calculation unit factorizes the unitary-transformed correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix.

36. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product U^HU of upper triangular matrix U by cholesky factorization.

37. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes input matrix R to product LL^H of lower triangular matrix L by cholesky factorization.

38. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product U^HDU of upper triangular matrix U and diagonal matrix D by modified cholesky factorization.

39. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said triangular matrix calculation unit factorizes an input matrix to product LDL^H of lower triangular matrix L and diagonal matrix D by modified cholesky factorization.

40. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein said correlation matrix calculation unit calculates a correlation matrix, applies a spatial smoothing technique to the correlation matrix, and outputs a resultant matrix.

41. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle (-θ).

42. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

43. (Original) A radio-wave arrival-direction estimating apparatus according to claim 34, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

44. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation matrix calculation unit for calculating a correlation matrix by correlation calculation of the complex digital signal between the antenna elements;

a triangular matrix calculation unit for factorizing the correlation matrix to a product of one of an upper triangular matrix and a lower triangular matrix;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the one of the upper triangular matrix and the lower triangular matrix; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

45. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

a receiving unit for converting frequency of a RF signal received by each of the antenna elements in said array antenna, demodulating the converted signal, and outputting the demodulated signal;

an A/D converter for converting the demodulated signal to a complex digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

46. (Original) A radio-wave arrival-direction estimating apparatus according to claim 45 further comprising a unitary transforming unit for unitary-transforming the correlation vector, wherein

the plurality of antenna elements are arranged linearly at a constant interval, and

said arrival-angle evaluation unit calculates an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the unitary-transformed correlation vector.

47. (Original) A radio-wave arrival-direction estimating apparatus according to claim 45, wherein

said array antenna includes a plurality of antenna elements arranged linearly at a constant interval, and

said arrival-angle evaluation unit comprises

a positive-region evaluation unit for calculating an evaluation value of an arrival-angle evaluation function for positive angle θ with reference to a bore-sight direction of said array antenna, and

a negative-region evaluation unit for converting the evaluation value by the positive-region evaluation unit to an arrival-angle evaluation value for negative angle $(-\theta)$.

48. (Original) A radio-wave arrival-direction estimating apparatus according to claim 45, wherein

said array antenna has a linear array shape, and

said arrival-angle evaluation unit sets an angle interval in an end fire direction of said array antenna to be larger than an angle interval in a bore-sight direction, and calculates an evaluation value of an arrival-angle evaluation function.

49. (Original) A radio-wave arrival-direction estimating apparatus according to claim 45, further comprising:

a high-accuracy arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function at an angle interval smaller than an angle interval calculated by said arrival-angle evaluation unit, in a predetermined angle range around the arrival angle supplied from said arrival-angle determination unit; and

a high-accuracy arrival-angle determination unit for highly accurately determining an arrival angle based on the evaluation value by said high-accuracy arrival-angle evaluation unit.

50. (Original) A radio-wave arrival-direction estimating apparatus comprising:

an array antenna including a plurality of antenna elements;

an intermediate-frequency receiving unit for performing frequency conversion and phase detection of a RF signal received by each of the antenna elements, and outputting an intermediate frequency signal;

an intermediate-frequency A/D converter for converting the intermediate frequency signal to an intermediate-frequency digital signal;

a digital orthogonal wave detector for orthogonally demodulating the intermediate-frequency digital signal;

a correlation vector calculation unit for calculating a correlation vector by correlation calculation between a reference antenna element and another antenna element, the reference antenna element corresponding to a selected complex digital signal;

an arrival-angle evaluation unit for calculating an evaluation value of an arrival-angle evaluation function every predetermined angle, the arrival-angle evaluation function being expressed using the correlation vector; and

an arrival-angle determination unit for determining an arrival angle based on the evaluation value by said arrival-angle evaluation unit.

51. - 110. (Cancelled)